WHEAT CULTIVARS RESISTANT TO RACES OF HESSIAN FLY

Production Research Report No. 134

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

CONTENTS

Washington, D.C. Issued November 1971

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402–Price 20 cents
Stock No. 0100–1437

WHEAT CULTIVARS RESISTANT TO RACES OF HESSIAN FLY

By R. L. Gallun and L. P. Reitz, *research entomologist*, Entomology Research Division, Agricultural Research Service, and Department of Entomology, Purdue University; *research agronomist*, Plant Science Research Division, Agricultural Research Service, respectively.

Today, the quality of our environment is a primary concern to everyone, including those in agriculture. Pollution problems in air, water, and land are rapidly becoming compounded, and major steps are being taken by State, Federal, and private agencies to protect the environment.

The development of insect-resistant cultivars is now receiving modest support and promises to become a major method of controlling insects. Resistant plants have built-in properties that kill insects, thereby eliminating or reducing the need for insecticides and the hazards of formulation, application, and runoff associated with their usage.

The purpose of this report is to present the distribution and production of cultivars resistant to the Hessian fly that are grown in the United States, to indicate some of the characteristics of each and the reactions to important diseases, and to discuss races of Hessian flies as they relate to resistant cultivars.

GENES FOR RESISTANCE

The production of an insect-resistant cultivar and the associated research require cooperative efforts by entomologists and plant breeders. This production may take 6 to 30 years, depending upon the complexity of the breeding program. Generally, cultivars contain agronomic traits other than insect resistance. Also, some are adapted to a specific area, and others have a wider range. In addition, biological strains or races of insects and diseases may develop on cultivars containing specific sources of resistance.

The research program involving the breeding of wheats for resistance to the Hessian fly, *Mayetiola destructor* (Say), is an example of highly successful cooperation between entomologists and plant breeders. It is not new. Cooperative programs to develop wheats resistant to the Hessian fly began with the Kansas, California, and Indiana Agricultural Experiment Stations and the U.S. Department of Agriculture (Painter, *1951*)[1] during the early part of the 20th century. They now involve many State experiment stations and the Entomology Research and Plant Science Research (formerly Crops Research) Divisions of the Agricultural Research Service, USDA.

Screening for wheat germ plasm that is resistant to the Hessian fly began during the early 1900's. The Dawson resistance was found in New York (Roberts and others, *1901*), and the Kawvale and Marquillo resistance genes were found in Kansas (Painter and others, *1940*). These genes are now present in resistant cultivars grown in the West. In 1935, the W38 (H3) and P.I. 94587[2] resistant genes were discovered at Purdue University, and in 1939, the Ribeiro (H5) resistance was also discovered there (Caldwell and Compton, *1939*).

The sources of resistance to the Hessian fly were subsequently analyzed to determine whether they differ from one another genetically and what number of genes was responsible

[1]The year in italic after the author's name is the key to the Literature Cited, p. 14.

[2]P.I. is an abbreviation for Plant Introduction number used by the Plant Science Research Division of ARS to accession all incoming, usually foreign, germ plasm.

for each type. For example, Cartwright and Wiebe (*1936*) studied the Dawson resistance and concluded that in California it was controlled by two independent dominant factors later designated H_1 and H_2 (Noble and Suneson, *1943*).

The Marquillo resistance was reported by Painter and others (*1940*) to be complex and to consist of several separate mechanisms. Noble and others (*1940*) stated that the resistance of Illinois No. 1 was independent of the H_1 and H_2 genes. Caldwell and others (*1946*) subsequently reported that the W38 selection from Illinois No. 1 had the H_3 gene for resistance. A recessive gene, h_4, was found in Java by Suneson and Noble (*1950*), though Cartwright and Noble (*1947*) had found the resistance of Java similar to that reported for W38. Shands and Cartwright (*1953*) stated that the Ribeiro resistance was caused by a fifth dominant gene, H_5. Allen and others (*1959*) reported that the H_6 gene was responsible for the resistance of a 42-chromosome derivative of the 28-chromosome durum wheat P.I. 94587. Also, studies of inheritance made by Caldwell and others (*1966b*) showed that four or more genes were responsible for resistance in this durum.

RACES OF HESSIAN FLY

During this period of time when genetic studies of resistance in wheat were being conducted, different host specific races of Hessian fly were also being studied (Gallun and others, *1961*). These races were either isolated from field populations or developed in the laboratory by interracial crosses. Seven races of Hessian fly have been developed and six are now being utilized in the wheat breeding programs of several States.

The Great Plains race is found in the wheat growing areas of western Kansas, but it has not been isolated from field populations in the eastern soft wheat region. This race is only capable of infesting wheats such as Turkey that are universally susceptible, many of which are grown in the hard red winter wheat region. The Great Plains race cannot infest wheats having the Kawvale, Marquillo, H_3, H_5, or H_6 genes for resistance.

Race A is the predominant race in the eastern soft wheat region and has been isolated from populations in northern Kansas, Indiana, Missouri, and Tennessee (Hatchett and Gallun, *1968*). Race A is able to infest all wheats susceptible to the Great Plains race and also wheats having the Kawvale or similar types of resistance, but it cannot infest wheats having H_3, H_5, H_6, or Marquillo genes for resistance.

Race B has been identified in northeastern Kansas, Indiana, Ohio, Illinois, Michigan, Missouri, and Tennessee. Race B is the predominant race in Indiana where over 80 percent of the wheat acreage is planted to wheats having the H_3 gene for resistance. This race is able to infest wheats susceptible to the Great Plains race and race A as well as wheats having the H_3 gene for resistance, but it is unable to infest wheats having the Marquillo, H_5, or H_6 genes for resistance.

Race C has been isolated in Indiana, northeastern Kansas, Tennessee, Missouri, and Michigan. It is able to infest wheats susceptible to the Great Plains race and Race A, and also wheats having the single gene resistance from P.I. 94587, but it is unable to infest wheats having the Marquillo, H_3, and H_5 genes for resistance. This race is almost extinct in areas where wheats with the H_3 gene have been growing for several years.

Race D has been found only in Indiana and there only in low density (Hatchett and Gallun, *1968*). It is able to infest wheats susceptible to the Great Plains race and races A, B, and C, but it is unable to infest wheats having the Marquillo or H_5 genes for resistance.

Race E is a new race of Hessian flies (Hatchett, *1969*). It was isolated from a sample of wheat collected in Georgia. This race reacts like the Great Plains race since it is able to infest the universally susceptible wheats but unable to infest wheats growing in the soft wheat region that have the Kawvale or similar genes for resistance. Race E is also unable to infest wheats having the H_5, the single gene resistance from P.I. 94587, or the Marquillo

genes for resistance. However, it is able to infest wheats having the H_3 gene for resistance.

Race F is a race recently developed in the laboratory by Soontorn Wootipreecha, a graduate student of entomology at Purdue University. This race was developed by a series of crosses and backcrosses involving the Great Plains race and race C. It behaves like race C in that it is virulent to wheats having the H_6 gene for resistance, but differs from race C in that it reacts like the Great Plains race and cannot infest wheats having the H_1H_2 genes for resistance. Also, race F cannot survive on wheats that have the H_5 or Marquillo genes. This race has not yet been isolated from the field.

These races are being used to evaluate wheats for resistance as developed by Cartwright and LaHue (*1944*) and to distinguish between wheats having different genes for resistance. They have also been used in genetic studies to learn more about the insects inherent variability (Gallun and Hatchett, *1969*, and Hatchett and Gallun, *1970*).

ESTIMATED ACREAGE OF CULTIVARS OF WHEAT AND THEIR REACTIONS TO RACES OF HESSIAN FLY

As a result of the various cooperative research programs, 26 wheat cultivars have been released, which contain one or more of the H_1H_2, H_3, H_6, Kawvale, and Marquillo genes for resistance to Hessian fly. The acreages cited in this report are preliminary estimates based on the national wheat variety survey for 1969 conducted by the USDA and cooperating State officials.

Table 1 gives the resistant cultivars released since 1942, their type of resistance, and source of release. Tables 2 and 3 show the estimated wheat acreage of wheats that are resistant to Hessian fly by wheat classes, cultivar, and individual State distribution.

During 1969, 24 wheat cultivars, resistant to the Hessian fly, were grown on an estimated 8½ million acres in 34 States or slightly over 15½ percent of the total wheat acreage in the United States for that year. This is actually a drop of approximately 1½ million acres from 1964 when 18 fly-resistant cultivars were grown on approximately 10 million acres in 34 States (Reitz and Briggle, *1966*). This loss in wheat acreage sown to Hessian fly resistant wheats was entirely in the hard red winter wheat region, mainly for the cultivars Ottawa, Pawnee, Omaha, and Ponca.

During the last decade, 17 of the resistant cultivars were released to wheat growers. They contain either the W38 (H_3) resistance, the single gene resistance from P.I. 94587 (H_6), the Kawvale resistance, the Dawson (H_1H_2) resistance, or the Marquillo resistance, or combinations of these. W38 provides protection against the Great Plains race and races A and C. The single gene resistance from P.I. 94587 is effective against the Great Plains race and races A and B (Gallun and others, *1961*); the Kawvale resistance and Dawson resistances are only effective against the Great Plains race; and the Marquillo resistance is effective against all known races.

The hard red winter wheats, Warrior, Gage, Parker, Pawnee, Omaha, and Ponca, carry the Kawvale or Marquillo sources of resistance. Ottawa, Shawnee, and other hard red winter wheats have the W38 resistance. These wheats were grown on more than 4 million acres in 20 States during 1969. In 1964, they were grown on 6 million acres.

The soft red winter wheats, Monon, Redcoat, Benhur, Knox 62, Reed, Georgia 1123, Riley, Dual, Riley 67, Arthur, Ace, and Logan, carry either the W38 or the single gene resistance of P.I. 94587. They were grown on over 4 million acres in 24 States during 1969. They increased in acreage slightly since 1964. In 1964, they were grown on slightly less than 4 million acres. The acreage grown to these soft wheats in 1969 was approximately one-third of that grown to all wheat cultivars in the eastern soft wheat region during that year. Ionia, a soft white winter wheat, was grown as foundation seed in 1969.

The hard red spring wheats, Russell and Lathrop, contain the W38 resistance and single gene resistance of P.I. 94587, respectively.

These wheats were confined to Wisconsin in 1969 and were grown on only 3,520 acres. Big Club 60, a club wheat, contains the Dawson resistance. It was grown on only 2,479 acres in California during 1969.

When based on the type of resistance present in a cultivar, those cultivars carrying the W38 resistance were grown on the most acreage—almost 4 million acres. The three cultivars containing the Marquillo resistance were grown on almost 2 million acres, and the Kawvale type cultivars were also grown on almost 2 million acres.

Thirteen States had over 50 percent of their total wheat acreage planted to Hessian fly resistant wheats. They were Arkansas, Delaware, Georgia, Illinois, Indiana, Iowa, Kentucky, Maryland, Missouri, New Jersey, Ohio, Pennsylvania, and Tennessee. Their combined wheat acreage of resistant wheats amounted to almost 5 million acres. In 1964, only eight States had over 50 percent of their wheat acreage sown to fly resistant cultivars.

TABLE 1.—*Wheat cultivars resistant to the Hessian fly*

Variety	Year released	Source	Type of resistance
Pawnee (C.I. 11669) [1]	1942	Nebraska Kansas	Kawvale
Poso 42 (C.I. 12244)	1942	California	Dawson (H_1H_2)
Poso 48 (C.I. 12691)	1948	do	Dawson (H_1H_2)
Big Club 43 (C.I. 12237)	1943	do	
Big Club 60 (C.I. 13643)	1962	do	Dawson (H_1H_2)
Ponca (C.I. 12128)	1951	Kansas	Marquillo
Dual (C.I. 13083)	1955	Indiana	W38 (H_3)
Russell (C.I. 12484)	1955	Wisconsin	W38 (H_3)
Todd (C.I. 13110)	1956	Kentucky	W38 (H_3)
Monon (C.I. 13278)	1959	Indiana	W38 (H_3)
Redcoat (C.I. 13170)	1960	do Pennsylvania	W38 (H_3)
Ace (C.I. 13384)	1960	Arkansas	W38 (H_3)
Omaha (C.I. 13015)	1960	Nebraska	Kawvale
Warrior (C.I. 13190)	1960	do	Kawvale
Ottawa (C.I. 12804)	1960	Kansas	W38 (H_3)
Georgia 1123 (C.I. 13292)	1960	Georgia	W38 (H_3)
Lathrop (C.I. 13457)	1961	Wisconsin	P.I. 94587 (H_6)
Reed (C.I. 13513)	1962	Indiana	W38 (H_3)
Knox 62 (C.I. 13701)	1962	do	P.I. 94587 (H_6)
Gage (C.I. 13532)	1963	Nebraska	Marquillo
Riley (C.I. 13702)	1965	Indiana	W38 (H_3)
Benhur (C.I. 14054)	1966	do	P.I. 94587 (H_6)
Riley 67 (C.I. 14110)	1967	do	W38 (H_3)
Parker (C.I. 13285)	1967	Kansas	Marquillo
Shawnee (C.I. 14157)	1967	do	W38 (H_3)
Arthur (C.I. 14425)	1968	Indiana	W38 (H_3)
Logan (C.I. 14156)	1968	Ohio	W38 (H_3)
Ionia (C.I. 14469)	1969	Michigan	W38 (H_3)

[1] C.I. signifies Cereal Investigation numbers assigned to certain cultivars by the Plant Science Research Division, ARS, USDA.

TABLE 2.—*Total estimated wheat acreage per resistant wheat cultivar by wheat classes, 1969*

Hessian fly resistant cultivar	Total 1969 acreage per cultivar	Percentage of total U.S. wheat acreage
	Acres	*Percent*
Club:		
Big Club 60	2,479	(1)
Hard red winter:		
Warrior	1,519,579	2.8
Gage	1,333,366	2.4
Ottawa	466,775	.8
Parker	338,903	.6
Pawnee	320,194	.6
Omaha	69,761	.2
Ponca	57,927	.2
Shawnee	57,849	.1
	4,164,354	7.7
Hard red spring:		
Lathrop	3,148	(1)
Russell	372	(1)
	3,520	
Soft red winter:		
Monon	2,352,597	4.3
Redcoat	564,378	1.0
Benhur	536,211	1.0
Knox 62	302,623	.6
Reed	271,751	.5
Georgia 1123	165,249	.3
Riley	66,308	.1
Dual	31,371	.1
Riley 67	22,267	(1)
Arthur	20,278	(1)
Ace	7,500	(1)
Logan	1,443	(1)
Ionia	(1)	(1)
	4,341,976	7.9
Total resistant cultivars	8,512,329	15.6

[1] Less than 0.01 percent.

TABLE 3.—*Estimated wheat acreage per State for each resistant wheat cultivar in 1969*

State and cultivar	Acreage grown	Percentage of total State wheat acreage
	Acres	*Percent*
Alabama:		
Georgia 1123	23,105	20.3
Monon	2,747	2.4
Benhur	1,529	1.3
Knox 62	856	.8
Ace	183	.2
Redcoat	136	.1
Total	28,556	25.1
Arkansas:		
Knox 62	111,355	29.3
Benhur	58,746	15.5
Monon	105,291	27.7
Ace	7,317	1.9
Georgia 1123	5,448	1.4
Ponca	415	.1
Riley	389	.1
Redcoat	79	.1
Total	289,040	76.1
California:		
Big Club 60	2,479	.6
Colorado:		
Warrior	704,611	22.6
Ottawa	532	(1)
Total	705,143	22.6
Delaware:		
Redcoat	13,611	61.9
Monon	5,130	23.3
Total	18,741	85.2
Georgia:		
Georgia 1123	56,941	58.1
Redcoat	376	.4
Total	57,317	58.5
Illinois:		
Monon	511,185	37.6
Gage	343,927	25.3
Benhur	186,731	13.7
Pawnee	100,533	7.4
Ottawa	85,114	6.3
Knox 62	22,388	1.6

See footnote at end of table.

See footnote at end of table.

TABLE 3.—*Estimated wheat acreage per State for each resistant wheat cultivar in 1969*—Continued

State and cultivar	Acreage grown	Percentage of total State wheat acreage
	Acres	*Percent*
Illinois—Con:		
Riley	13,210	.9
Ponca	9,849	.7
Parker	5,956	.4
Omaha	3,274	.2
Dual	2,706	.2
Arthur	2,520	.2
Reed	639	.2
Shawnee	149	.1
Redcoat	77	(1)
Total	1,288,258	94.8
Indiana:		
Monon	527,128	55.1
Benhur	154,791	16.2
Riley	51,320	5.4
Knox 62	45,897	4.8
Reed	42,592	4.5
Redcoat	38,775	4.1
Riley 67	12,563	1.3
Arthur	6,935	.7
Pawnee	5,907	.6
Dual	2,580	.3
Ottawa	1,932	.2
Gage	1,139	.1
Total	891,559	93.3
Iowa:		
Gage	29,354	56.5
Pawnee	6,468	12.4
Ottawa	4,290	8.3
Omaha	2,055	3.9
Ponca	1,031	2.0
Monon	332	.6
Parker	70	.1
Total	43,600	83.8
Kansas:		
Gage	361,650	3.3
Parker	265,794	2.5
Ottawa	260,454	2.4
Warrior	108,343	1.0
Shawnee	57,700	.5
Pawnee	50,274	.5
Ponca	9,797	.1
Omaha	617	(1)
Total	1,114,629	10.3

See footnote at end of table.

State and cultivar	Acreage grown	Percentage of total State wheat acreage
	Acres	*Percent*
Kentucky:		
Benhur	52,883	21.8
Monon	45,260	18.6
Knox 62	33,873	13.9
Redcoat	4,713	2.0
Dual	1,365	.6
Arthur	968	.4
Reed	788	.3
Total	139,850	57.6
Louisiana:		
Georgia 1123	29,428	35.9
Monon	2,312	2.8
Total	31,740	38.7
Maryland:		
Redcoat	82,423	65.4
Monon	7,885	6.3
Dual	1,244	.9
Benhur	97	.1
Total	91,649	72.7
Michigan:		
Monon	91,635	13.5
Redcoat	9,745	1.4
Reed	3,194	.5
Benhur	2,921	.4
Dual	1,685	.3
Riley	1,389	.2
Arthur	1,355	.2
Ionia	(1)	(1)
Total	111,924	16.5
Mississippi:		
Georgia 1123	43,200	28.2
Monon	11,728	7.7
Total	54,928	35.9
Missouri:		
Monon	361,824	30.4
Gage	145,923	12.3
Pawnee	112,812	9.5
Parker	65,538	5.5
Benhur	20,514	1.7
Ottawa	14,179	1.2
Ponca	14,005	1.2

See footnote at end of table.

TABLE 3.—*Estimated wheat acreage per State for each resistant wheat cultivar in 1969*—Continued

State and cultivar	Acreage grown	Percentage of total State wheat acreage
	Acres	*Percent*
Missouri—Con:		
Knox 62	11,112	.9
Redcoat	8,296	.7
Dual	5,039	.4
Arthur	2,197	.2
Riley 67	1,844	.1
Total	763,283	64.1
Montana:		
Warrior	261,932	6.9
Gage	1,115	(1)
Total	263,047	6.9
Nebraska:		
Warrior	407,567	13.6
Gage	385,804	12.9
Ottawa	90,204	3.0
Omaha	51,436	1.7
Pawnee	42,353	1.4
Ponca	2,168	.1
Total	979,532	32.7
New Jersey:		
Redcoat	29,454	61.4
Benhur	1,712	3.6
Dual	399	.8
Monon	145	.3
Ponca	36	(1)
Total	31,746	66.1
New Mexico:		
Warrior	1,558	.5
New York:		
Redcoat	2,062	1.0
Pawnee	66	.1
Total	2,128	1.1
North Carolina:		
Knox 62	4,110	1.8
Georgia 1123	1,062	.5
Redcoat	151	(1)
Total	5,323	2.3
North Dakota:		
Warrior	624	(1)

See footnote at end of table.

State and cultivar	Acreage grown	Percentage of total State wheat acreage
	Acres	*Percent*
Ohio:		
Monon	543,672	49.2
Reed	216,310	19.6
Redcoat	79,404	7.2
Benhur	50,642	4.6
Dual	8,592	.8
Riley 67	7,476	.7
Knox 62	2,624	.2
Arthur	1,737	.1
Logan	1,443	.1
Total	911,900	82.5
Oklahoma:		
Gage	11,208	.2
Ponca	5,610	.1
Ottawa	2,760	.05
Parker	1,221	.05
Total	20,799	.4
Pennsylvania:		
Redcoat	255,198	74.2
Dual	5,868	1.7
Reed	315	.1
Total	261,381	76.0
South Carolina:		
Georgia 1123	6,065	6.4
Knox 62	273	.3
Total	6,338	7.7
South Dakota:		
Gage	44,843	2.1
Omaha	12,379	.6
Ottawa	6,991	.3
Warrior	4,677	.2
Total	68,890	3.2
Tennessee:		
Monon	132,706	48.6
Knox 62	18,484	6.8
Reed	6,958	2.5
Benhur	4,731	1.8
Arthur	4,566	1.7
Parker	324	.1
Redcoat	50	(1)
Total	167,819	61.5

See footnote at end of table.

TABLE 3.—*Estimated wheat acreage per State for each resistant wheat cultivar in 1969*—Continued

State and cultivar	Acreage grown	Percentage of total State wheat acreage
	Acres	*Percent*
Texas:		
Knox 62	51,123	1.2
Ponca	14,941	.4
Warrior	3,765	.1
Gage	2,234	.1
Monon	2,051	(1)
Benhur	473	(1)
Riley 67	384	(1)
Total	74,971	1.8
Virginia:		
Redcoat	33,559	19.2
Knox 62	528	.3
Reed	266	.1
Monon	91	.1
Dual	58	(1)
Total	34,502	19.7
West Virginia:		
Redcoat	6,269	36.9
Dual	761	4.5
Reed	482	2.8
Pawnee	478	2.8
Monon	117	.7
Total	8,107	47.7
Wisconsin:		
Gage	4,279	9.1
Lathrop	3,148	6.7
Monon	1,358	2.9
Pawnee	1,303	2.8
Dual	1,074	2.3
Benhur	441	.9
Russell	372	.8
Reed	207	.4
Ponca	75	.2
Total	12,257	26.1
Wyoming:		
Warrior	26,502	9.0
Gage	1,890	.6
Ottawa	319	.2
Total	28,711	9.8

[1] Less than 0.01 percent.

DESCRIPTION OF RESISTANT WHEAT CULTIVARS

Pawnee, a hard red winter wheat, was developed by cooperative effort of the Kansas and Nebraska Agricultural Experiment Stations and the present Plant Science Research Division and Entomology Research Division of the Agricultural Research Service, USDA. The cultivar was released by the Nebraska and Kansas Agricultural Experiment Stations during 1942 and 1943, respectively. In 1954, this cultivar was the leading hard red winter wheat in acreage planted. In 1964, it was grown on 1¾ million acres (Reitz and Briggle, *1966*). Since 1964, it has declined in acreage, and in 1969, it was only grown on a little more than 320,000 acres. Pawnee has the Kawvale resistance and is effective only against the Great Plains race in States west of central Kansas. It is an awned, white-glumed cultivar with short straw that matures early and has a moderate level of protein. Also, it is moderately resistant to leaf rust, resistant to loose smut, and susceptible to powdery mildew and soilborne mosaic (Reitz and Laude, *1943*).

Poso, in this report, refers to Poso 42 and Poso 48. Poso 42 has the Dawson (H_1H_2) genes for resistance to Hessian flies and is effective against the California and western populations but ineffective against the majority of field populations east of central Kansas. It was developed in a backcrossing program by the California Agricultural Experiment Station at Davis in cooperation with the present Plant Science Research and Entomology Research Divisions. Poso 48 has a mixed reaction to Hessian fly, and when grown, was limited to California where it was used on 1,345 acres in 1964. In 1969, no Poso was recorded as being grown at all. It is a spring-type, awned, white-glumed, soft, short, stiff-strawed club wheat that ma-

tures early and is resistant to several races of bunt and stem rust (Bayles and Clark, *1954*).

Big Club 43 and *Big Club 60* are the resistant forms of the cultivar. They were developed in California in the backcrossing program of the California Agricultural Experiment Station at Davis in cooperation with the present Plant Science Research and Entomology Research Divisions. The cultivars have the H_1H_2 genes for resistance to the Hessian fly and are effective against California populations of this insect. The 1969 acreage of Big Club 60 was confined to California and was recorded as 2,479 acres. The cultivar is a spring-type, soft, white-glumed wheat, midtall to tall, that is resistant to some races of bunt and stem rust (Bayles and Clark, *1954*).

Ponca, a hard red winter wheat, was developed by the Kansas Agricultural Experiment Station at Manhattan in cooperation with the present Plant Science Research and Entomology Research Divisions. It was released to growers by the Kansas and Oklahoma Agricultural Experiment Stations in the fall of 1951. The cultivar has the Marquillo type of resistance and is effective against all known races of Hessian flies. In 1969, it was only grown on 58,000 acres in 10 States. In 1964, it grew on approximately 314,000 acres.

Ponca is a high-yielding, awned, white-glumed wheat with short, medium-strong straw that matures early and has a moderate level of protein. Ponca is moderately resistant to leaf rust and loose smut, but susceptible to powdery mildew and soilborne mosaic (Laude and others, *1952*; Bayles and Clark, *1954*).

Dual, the first soft red winter wheat released that had effective field resistance to the Hessian fly, has the W38 (H_3) gene for resistance and is effective against the Great Plains race and races A and C. The cultivar was developed by the Purdue University Agricultural Experiment Station and the present Plant Science Research and Entomology Research Divisions after 32 years of breeding and research during which desirable characteristics from eight original parent cultivars were combined. It was released in 1955. In 1964, it was grown on approximately 310,000 acres in 19 States. During 1969, it was grown on 31,371 acres in 12 States. Dual is an awnleted, white-glumed, short to midtall, midstrong-stemmed wheat that matures in midseason and has a relatively low level of protein. It is moderately resistant to leaf rust and soilborne mosaic, moderately resistant to powdery mildew, and susceptible to loose smut (Caldwell and others, *1959a*).

Russell, the first red spring wheat released that was resistant to the Hessian fly, carries the W38 (H_3) gene for resistance to races A and C and the Great Plains race. It was developed in a cooperative effort by the Wisconsin Agricultural Experiment Station and the present Plant Science Research and Entomology Research Divisions, and was released by the Wisconsin Agricultural Experiment Station in 1955. During 1964, it was grown on approximately 2,000 acres. During 1969, it was grown on only 372 acres in Wisconsin. This cultivar is an awned, white-glumed wheat with midtall, weak straw that matures at midseason and has a moderate level of protein. It is susceptible to leaf rust, moderately resistant to powdery mildew, and resistant to loose smut (Briggle and Reitz, *1963*).

Todd, a soft red winter wheat that carries the W38 (H_3) gene for resistance to Hessian fly races A and C and to the Great Plains race, was released by Kentucky in 1956, but it is now rarely grown. It was reported on only 33 acres in Kentucky during 1964 and was not recorded as being grown in 1969. The cultivar is awnless and white-glumed with midtall, midstrong straw, matures early to midseason, and has a low level of protein. It is susceptible to leaf rust, moderately resistant to powdery mildew, and resistant to soilborne mosaic and loose smut (Briggle and Reitz, *1963*).

Monon is a soft red winter wheat carrying the W38 (H_3) gene for resistance to the Great Plains race and races A and C. It was developed by the Purdue Agricultural Experiment Station and the present Plant Science Research and Entomology Research Divisions and was distributed to certified wheat growers in 1959. In 1969, more acres were planted to Monon than to any other cultivar resistant to the Hessian fly. In 1964, it was grown on more than 1 million acres in 17 States, and in 1969 it was grown on almost 2½ million acres in 19 States.

The cultivar is an awnleted, white-glumed wheat, with short, midstrong straw that matures early and has a low level of protein. Monon is susceptible to present Indiana races of leaf rust, resistant to soilborne mosaic, moderately susceptible to powdery mildew, and susceptible to loose smut (Caldwell and others, *1959b*).

Redcoat, a soft red winter wheat, has the W38 (H_3) gene for resistance to races A and C and the Great Plains race. It was developed by the Purdue University Agricultural Experiment Station in cooperation with the present Plant Science Research and Entomology Research Divisions and was released jointly with Pennsylvania in 1960. During 1964, it was grown on 522,536 acres, and during 1969, it was grown on 564,378 acres in 18 States and ranked fourth in the number of acres seeded to resistant cultivars that year. The cultivar is an awnless, white-glumed wheat of midheight with strong straw that matures in midseason and has a low level of protein. Redcoat is resistant to leaf rust, powdery mildew, and soilborne mosaic but moderately susceptible to loose smut. It has a tendency to shatter during a dry harvest (Caldwell and others, *1960*).

Ace, a soft red winter wheat, was developed in 1960 by the Arkansas Agricultural Experiment Station in cooperation with the Entomology Research Division. It has the W38 (H_3) gene for resistance to races A and C and to the Great Plains race, and during 1969, it was grown on 7,500 acres in two States. It was only grown on 9,678 acres in 1964. Ace is an awnleted, white-glumed cultivar, short to midtall, midstrong to strong in straw strength, that matures midseason to late, and has a moderate level of protein. It is resistant to leaf rust and soilborne mosaic and moderately resistant to powdery mildew and loose smut (Briggle and Reitz, *1963*).

Omaha, a hard red winter wheat, was developed by the Nebraska Agricultural Experiment Station in cooperation with the present Plant Science Research and Entomology Research Divisions and was released in 1960. It has the Kawvale resistance to the Hessian fly. In 1964, it grew on 653,454 acres in seven States. It was grown on 69,761 acres in five States during 1969 and ranked 12th in acreage planted to resistant cultivars. The cultivar is awned and white-glumed, with moderately short, strong-stemmed straw, and superior winter hardiness. It matures early and has a high level of protein. Omaha is susceptible to leaf rust, stem rust, and streak mosaic, but resistant to soilborne mosaic, bunt, and shattering, and moderately resistant to loose smut (Johnson and others, *1961b*).

Warrior, a hard red winter wheat, was developed by the Nebraska Agricultural Experiment Station in cooperation with the present Plant Science Research and Entomology Research Divisions and was released in 1960. It has the Kawvale resistance to the Hessian fly. Since it was grown on 1,519,579 acres in nine States during 1969, it ranked second in acreage planted to resistant cultivars. In 1964, it grew on 1,477,301 acres in 10 States. Warrior is an awned, white-glumed cultivar with short, strong straw that matures in midseason and has a moderate level of protein. It is susceptible to leaf rust, stem rust, and soilborne mosaic and resistant to loose smut (Johnson and others, *1961a*).

Ottawa, a hard red winter wheat, was developed by the Kansas Agricultural Experiment Station in cooperation with the present Plant Science Research and Entomology Research Divisions and was released by Kansas in 1960. It carries the W38 (H_3) gene for resistance to the Great Plains race and races A and C. Ottawa was grown in 10 States on only 466,775 acres during 1969. In 1964, it was grown on almost 2 million acres, but since then it has been largely replaced by Gage. The cultivar is moderately susceptible to loose smut and bunt and susceptible to streak mosaic. It is an awned, white-glumed cultivar with moderately short, stiff straw that matures early and is resistant to leaf rust in the adult stage; it is also resistant to race 56 but not to race 15B of stem rust and soilborne mosaic (Briggle and Reitz, *1963*).

Georgia 1123 was developed by the Georgia Agricultural Experiment Station in cooperation with the present Plant Science Research and Entomology Research Divisions and was released in 1960. In 1964, it grew on 160,048 acres. During 1969, it was grown on 165,249 acres in

seven States. Georgia 1123 has the W38 (H_3) gene for resistance to races A and C and to the Great Plains race. The cultivar is an awnless, white-glumed wheat with short to midtall and midstrong to strong straw that matures very early and has a moderate level of protein. It is resistant to leaf rust and soilborne mosaic and susceptible to powdery mildew and loose smut (Gore and Stacy, *1961*).

Lathrop, a Wisconsin spring wheat, was the first wheat cultivar released that carries the durum P.I. 94587 resistance in a common type of wheat. It was developed by the Wisconsin Agricultural Experiment Station in cooperation with the present Plant Science Research and Entomology Research Divisions and was released to Wisconsin growers of certified seed in 1961. Lathrop is resistant to races A and B and to the Great Plains race. In 1969, it was grown on 3,148 acres in Wisconsin, slightly more than its 1964 acreage of 2,931 acres. The cultivar is a white-glumed wheat that matures in midseason, is midtall, and is moderately resistant to leaf rust; it is also resistant to some races of stem rust and susceptible to loose smut (Briggle and Reitz, *1963*).

Reed, a soft red winter wheat, carries the W38 (H_3) gene for resistance to races A and C, and to the Great Plains race. It is susceptible to races B and D. It was developed by the Purdue University Agricultural Experiment Station in cooperation with the present Plant Science Research and Entomology Research Divisions and was released to farmers in 1962. It was grown on 271,951 acres in 10 States during 1969. This is more than 150,000 acres more than its 1964 acreage of 118,346 acres. The cultivar is an awnleted, white-glumed wheat with outstanding straw strength and erectness that is resistant to some races of leaf rust, moderately susceptible to loose smut and powdery mildew, and resistant to soilborne mosaic in Indiana soils (Patterson and others, *1964*; Briggle and Reitz, *1963*).

Knox 62, a soft red winter wheat, is the first winter wheat carrying the P.I. 94587 resistance to Hessian fly races A and B and to the Great Plains race. It is susceptible to races C and D. It was developed by the Purdue University Agricultural Experiment Station in cooperation with the present Plant Science Research and Entomology Research Divisions and was released to farmers in 1962. In 1964, it grew on 172,436 acres, and in 1969, it grew on 302,623 acres in 12 States. This cultivar is the progeny of a backcross of Knox to a cultivar that was resistant to the Hessian fly. Knox 62 has good straw strength, high test weight, and is moderately resistant to leaf rust; it is slightly susceptible to powdery mildew and is resistant to the soil-borne mosaic common in Indiana soils (Briggle and Reitz, *1963*).

Gage, a hard red winter wheat, was released by the Nebraska Agricultural Experiment Station in 1963. In 1969, Gage was grown on 1,333,366 acres in Nebraska and ranked third in acreage planted to fly resistant wheats. This is an increase of more than 1 million acres since 1964. The cultivar has the Marquillo resistance to the Hessian fly (moderately resistant), excellent resistance to leaf rust and loose smut, and moderate resistance to soilborne mosaic (Johnson and Schmidt, *1963*).

Riley, a soft red winter wheat, was produced by the joint efforts of the Purdue Agricultural Experiment Station and the present Plant Science Research and Entomology Research Divisions, and it was released to wheat growers in 1965. In 1969, it was grown on 66,308 acres in four States. Riley has the H_3 (W38) gene for resistance to the Great Plains race and to races A and C of the Hessian fly, and is susceptible to races B and D. It is a well-adapted, high-yielding cultivar that grows in the soft winter wheat area. Also, it has excellent standing ability under high fertility and high resistance to loose smut and soilborne mosaic although it is moderately susceptible to powdery mildew and new races of leaf rust (Caldwell and others, *1965*).

Benhur is a high-yielding, soft red winter wheat developed by the Purdue Agricultural Experiment Station in cooperation with the present Plant Science Research and Entomology Research Divisions and was released to wheat growers in 1966. Benhur has the H_6 (P.I. 94587) gene for resistance to the Great Plains race and to races A and B. It is susceptible to races C and D. It is a white-chaffed, beardless, short-awnleted cultivar that is resistant to loose smut, powdery mildew, stem rust, and leaf rust (Caldwell and others, *1966a*). It was grown on 536,211 acres in 13 States during 1969.

Riley 67, a soft red winter wheat, was developed by the Purdue Agricultural Experiment Station in cooperation with the present Plant Science Research and Entomology Research Divisions and was released in 1967. In 1969, it was grown on 22,267 acres in four States. The cultivar has the W38 resistance to the Great Plains race and to races A and C. It is also susceptible to races B and D. It has high resistance to loose smut and is immune to the new races of leaf rust that attack Riley, Monon, and Knox 62. Also, it is a high-yielding, stiff-straw wheat (Caldwell and others, *1967*).

Parker is a hard red winter wheat that originated in Kansas from a series of crosses begun in 1920. This cultivar was produced by the cooperative efforts of the Kansas State University Departments of Agronomy and Entomology and the present Plant Science Research and Entomology Research Divisions and was released during 1967. In 1969, it was grown on 338,903 acres in six States. The cultivar has the Marquillo genes for resistance to all known races of the Hessian fly. It is a white-glumed, short, stiff-strawed wheat that matures early and has above average test weight. Also, in the adult stage, it has moderate resistance to many races of leaf rust. Parker is moderately susceptible to bunt and loose smut and susceptible to wheat streak mosaic, soilborne mosaic, and stem rust (Heyne and Painter, *1968*).

Shawnee, a hard red winter wheat, is a Kansas selection from the cultivar Ottawa. It was increased and distributed to Kansas growers in the fall of 1967 (Heyne and Finney, *1968*).

Shawnee resists some leaf rust races, race 56 of stem rust and soilborne mosaic virus. Like Ottawa, it carries the H_3 gene for resistance to the Great Plains race and races A and C, and is susceptible to races B and D. Shawnee was grown on 57,849 acres in two States during 1969.

Arthur, a soft red winter wheat that was released to wheat growers during 1968, was developed by the Department of Botany and Plant Pathology, Agronomy, and Entomology at Purdue University and the Entomology Research and Plant Science Research Divisions. In 1969, it was grown on 20,278 acres in seven States. The cultivar has the H_3 gene for resistance to Hessian fly races A and C but is susceptible to race B, the predominant race in Indiana, and also race D. It was released because of its superior yield and excellent test weight. Arthur is an awnleted, short, stiff-strawed cultivar that is resistant to stem rust, moderately resistant to leaf rust, and resistant to powdery mildew and loose smut. It also has a high level of resistance to soilborne mosaic (Schafer and others, *1968*).

Logan is a soft red winter wheat released by the Ohio Agricultural Research and Development Center in 1968. Hessian fly tests were conducted by the Entomology Research Division.

It is early to midseason in maturity and has short to midtall strong stems. Logan has moderate resistance to currently predominant races of leaf rust and has shown very little loose smut from natural infestion. It is susceptible to the currently prevalent races of stem rust (Lafever, *1968*).

Logan contains the W38 resistance to Hessian fly races A and C, but is susceptible to races B and D. It was grown on a little more than 1,400 acres in Ohio during 1969.

Ionia is the first soft, white winter wheat developed as an improved variety that has the H_3 gene for resistance to Hessian fly. It was developed cooperatively by the Michigan Agricultural Experiment Station and the Entomology Research and Plant Science Research Divisions. Ionia was released to foundation seed growers in the fall of 1969 by the Michigan Agricultural Experiment Station. Ionia is midseason and midtall, with a white stem. It is resistant to the leaf rust races prevalent in Michigan at the time of release. It is susceptible to powdery mildew and stem rust. It is a low protein, soft, white wheat well suited for pastry flour. (Unpublished information from E. H. Everson, Prof., Crops and Soils Science, Michigan State University, East Lansing, Mich.)

IMPACT OF RESISTANT WHEATS ON HESSIAN FLY POPULATIONS

During 1969, 13 States in the eastern soft wheat region had more than 50 percent of their wheat acreage sown to wheats that are resistant to the Hessian fly. Most of these wheats carry the H_3 gene for resistance. The selection pressure that this specialization is causing (and the resultant tendencies for new races to develop) is now becoming apparent. For example, in 1964 the wheat cultivar Georgia 1123 was grown on about 75 percent of Georgia's wheat acreage. However, by 1968, when the senior author visited fields planted to this cultivar near Albany, Ga., he found them almost destroyed by the Hessian fly. Also during 1964, about 80 percent of Indiana's wheat acreage was sown to wheats having the H_3 gene for resistance, but in 1967 a field of Monon and a field of Riley wheat in southern Indiana had infestations that damaged over 50 percent of the crop (Gallun and Hatchett, *1967a*). Races B and D were isolated from samples collected from these fields. The 1970 Hessian fly survey records from Illinois, Indiana, Michigan, and Ohio also show fields of resistant wheat that were infested by new races.

These instances of infestations of Hessian flies on wheats having genes for resistance are strong evidence that new races are developing in localized areas where wheats having similar genes for resistance have been growing for several years. However, this does not mean that resistant cultivars are not protecting wheat crops from serious damage. With the exception of isolated fields of resistant wheats becoming infested, the majority of certified wheat fields in Illinois, Indiana, Michigan, and Ohio surveyed the past 3 years have shown average infestations of less than 10 percent for each State. Many fields had no infestations (Gallun and Hatchett, *1967a*, *1967b;* Gallun and Everson, *1967*).

Although resistant wheats are thus usually performing well in suppressing populations of Hessian flies, the instances of damage indicate that we cannot be content with the capacity of our present wheat cultivars to suppress populations forever. Because of its high degree of genetic variability (Gallun and Hatchett, *1969*; Hatchett and Gallun, *1970*), the Hessian fly will continue to be a threat and should be considered as such when new wheat cultivars are bred. Moreover, the genetics of both the wheat plant and the insect should be studied continuously to obtain more insight into this complex relationship between host plant and insect.

We must continue to search for and maintain pure cultures of new races of Hessian flies and must use them to evaluate wheats for new sources of resistance. Also, we must make use of other mechanisms of resistance besides antibiosis, the one mechanism that is currently being utilized. Antibiosis, although an excellent mechanism, causes the high selection pressure that favors variants capable of surviving on wheats having specific genes for resistance. This situation could be alleviated by combining different genes for resistance in the same plant or by introducing more than one mechanism. Either method would reduce the possibility of mutation that could overcome the resistant genes present in the plant.

The use of nonpreference of oviposition would be an advantageous new mechanism because selection pressure for development of new races would not occur. Adults not preferring a specific host plant for oviposition would oviposit on native grasses or alternate host plants that are more preferred, and the frequency of genes in populations for virulence to specific wheats would not be changed to any great extent. Also, tolerance in wheat to insect feeding by growth of new tillers or stiffer straw is another mechanism that would be advantageous in a resistant wheat, but it would not suppress populations.

If acreages of wheats resistant to the Hessian fly continue to increase in the United States, there will certainly be additional new races building up in localized areas, particularly in the States where almost all of the wheats are

fly resistant and have one source of resistance. If we are to maintain our lead in the race between the developing races and resistant wheats, we will require dynamic breeding programs to incorporate new sources of resistance into present breeding lines, different mechanisms of resistance, and combinations of genes for resistance.

SUMMARY

During 1969, 24 wheat cultivars that are resistant to the Hessian fly, *Mayetiola destructor* (Say), and that contain the Dawson, W38 (H_3), P.I. 94587, Marquillo, and Kawvale sources of resistance, were grown on almost 8½ million acres in 34 States. The soft red winter wheats developed in Indiana—Monon, Dual, Redcoat, Knox 62, Reed, Riley, Riley 67, Benhur, and Arthur—were grown on more than 4 million acres in 24 States. All except Knox 62 and Benhur contain the W38 (H_3) source of resistance to races A and C and the Great Plains race. Knox 62 and Benhur contain the single gene resistance from P.I. 94587 to the Great Plains race and races A, B, and E.

Ace, Georgia 1123, and Logan are soft red winter wheats bred in Arkansas, Georgia, and Ohio, respectively. They contain the H_3 gene for resistance. They were grown on approximately 174,000 acres. The hard red winter wheats Ottawa and Shawnee (containing the W38 resistance); Ponca, Gage, and Parker (containing the Marquillo resistance); and Pawnee, Warrior, and Omaha (containing the Kawvale resistance), all bred in Kansas and Nebraska, in cooperation with ARS, were grown on about 4 million acres in 18 States. They gave protection against the Great Plains race found in the hard winter wheat region. The club wheat, Big Club 60, was grown only in California on about 2,500 acres; this wheat contains the Dawson (H_1+H_2) source of resistance to the Great Plains race of the Hessian fly. Two hard red spring wheats, Lathrop and Russell, were grown on about 3,500 acres in Wisconsin. Lathrop has the P.I. 94587 resistance to races A and B, and Russell has the W38 resistance to races A and C.

Seven races of Hessian flies have been isolated in the United States. The Great Plains race is most prevalent west of central Kansas. Races A, B, C, D, and E are found in the eastern soft wheat region where race A is generally predominant, although races B and E are most prevalent in certain areas of Indiana and Georgia, respectively. Races B and E differ from one another in their ability to infest wheats having the Dawson, W38, and P.I. 94587 sources of resistance. Race F, a new race capable of infesting wheats having the W38 resistance but not the Seneca type of resistance, has been bred in the laboratory.

LITERATURE CITED

Allan, R. E., Heyne, E. G., Jones, E. T., and Johnston, C. O.
1959. genetic analysis of ten sources of hessian fly resistance, their interrelationships and association with leaf rust reaction in wheat. Kans. Agr. Expt. Sta. Tech. Bul. 104, 51 pp.

Bayles, B. B., and Clark, J. A.
1954. classification of wheat varieties grown in the united states in 1949. U.S. Dept. Agr. Tech. Bul. 1083, 173 pp.

Briggle, L. W., and Reitz, L. P.
1963. classification of triticum species and of wheat varieties grown in the united states. U.S. Dept. Agr. Tech. Bul. 1278, 135 pp.

Caldwell, R. M., Cartwright, W. D., and Compton, L. E.
1946. inheritance of hessian fly resistance derived from w38 and durum p.i. 94587. Amer. Soc. Agron. Jour. 38(5): 398-409.

——— Cartwright, W. B., Compton, L. E., and others.
1959a. dual, a hessian fly resistant soft red winter wheat. Purdue Univ. Agr. Expt. Sta. Res. Bul. 681, 20 pp.

——— Cartwright, W. B., Compton, L. E., and others.
1960. redcoat soft red winter wheat. Purdue Univ. Agr. Expt. Sta. Mimeo. ID-44.

——— and Compton, L. E.
1939. wheat breeding for combined resistances to disease and hessian fly. Ind. Agr. Expt. Sta. Ann. Rpt. 39, 41-42 pp.

CALDWELL, R. M., COMPTON, L. E., CARTWRIGHT, W. B. and others.
1959b. MONON WHEAT. Purdue Univ. Coop. Ext. Serv. Mimeo. ID–36.
——— COMPTON, L. E., PATTERSON, F. L., and others.
1965. RILEY SOFT RED WINTER WHEAT, EARLY, STIFF AND RESISTANT TO LOOSE SMUT. Purdue Univ. Agr. Expt. Sta. Res. Prog. Rpt. 200, 4 pp.
——— COMPTON, L. E., PATTERSON, F. L., and others.
1966a. BENHUR SOFT RED WINTER WHEAT, EARLY, AND RESISTANT TO DISEASES AND HESSIAN FLY. Purdue Univ. Agr. Expt. Sta. Res. Prog. Rpt. 257, 4 pp.
——— COMPTON, L. E., PATTERSON, F. L., and others.
1967. RILEY 67, SOFT RED WINTER WHEAT RESISTANT TO LEAF RUST AND LOOSE SMUT. Purdue Univ. Res. Prog. Rpt. 309, 3 pp.
——— GALLUN, R. L., and COMPTON, L. E.
1966b. GENETICS AND EXPRESSION OF RESISTANCE TO HESSIAN FLY, PHYTOPHAGA DESTRUCTOR (SAY). 2d Internatl. Wheat Genetics Symposium Proc. 2: 462-463.
CARTWRIGHT, W. B., and LAHUE, D. A.
1944. TESTING WHEATS IN THE GREENHOUSE FOR HESSIA FLY RESISTANCE. Jour. Econ. Ent. 37(3): 385-387.
——— and NOBLE, W. B.
1947. STUDIES ON BIOLOGICAL RACES OF THE HESSIAN FLY. Jour. Agr. Res. 75: 147-153.
——— and WIEBE, G. A.
1936. INHERITANCE OF RESISTANCE TO THE HESSIAN FLY IN WHEAT CROSSES DAWSON X POSO AND DAWSON X BIG CLUB. Jour. Agr. Res. 52: 691-695.
GALLUN, R. L., DEAY, H. O., and CARTWRIGHT, W. B.
1961. FOUR RACES OF HESSIAN FLY SELECTED AND DEVELOPED FROM AN INDIANA POPULATION. Purdue Univ. Agr. Expt. Sta. Res. Bul. 732, 7 pp.
——— and EVERSON, E. H.
1967. REACTION OF MICHIGAN WHEATS TO POPULATIONS OF HESSIAN FLY. Ent. Res. Div. ARS-USDA, Spec. Rpt. W-259, 6 pp.
——— and HATCHETT, J. H.
1967a. REACTION OF INDIANA WHEATS TO POPULATIONS OF HESSIAN FLY. Ent. Res. Div. ARS-USDA, Spec. Rpt. W-256, 10 pp.
——— and HATCHETT, J. H.
1967b. REACTION OF OHIO WHEATS TO POPULATIONS OF HESSIAN FLY. Ent. Res. Div. ARS-USDA, Spec. Rpt. W-257, 12 pp.
——— and HATCHETT, J. H.
1969. GENETIC EVIDENCE OF ELIMINATION OF CHROMOSOMES IN THE HESSIAN FLY. Ann. Ent. Sov. Amer. 62(5): 1095-1101.
GORE, U. R., and STACY, S. V.
1961. GEORGIA 1123, A NEW HESSIAN FLY RESISTANT WHEAT. Ga. Agr. Res. 3(1): 8-9.
HATCHETT, J. H.
1969. RACE E, SIXTH RACE OF HESSIAN FLY, MAYETIOLA DESTRUCTOR (SAY), DISCOVERED IN GEORGIA WHEAT FIELDS. Ann. Ent. Soc. Amer. 62(3): 677-678.
HATCHETT, J. H., and GALLUN, R. L.
1968. FREQUENCY OF HESSIAN FLY, MAYETIOLA DESTRUCTOR (SAY), RACES IN FIELD POPULATIONS. Ann. Ent. Soc. Amer. 61(6): 1446-1449.
——— and GALLUN, R. L.
1970. GENETICS OF THE ABILITY OF THE HESSIAN FLY, MAYETIOLA DESTRUCTOR, TO SURVIVE ON WHEATS HAVING DIFFERENT GENES FOR RESISTANCE. Ann. Ent. Soc. Amer. 63(5): 1400-1407.
HEYNE, E. G., and FINNEY, K. F.
1968. REGISTRATION OF SHAWNEE WHEAT. Crop Sci. 8(4): 512.
——— and PAINTER, R. H.
1968. REGISTRATION OF PARKER WHEAT. Crop Sci. 7: 280.
JOHNSON, V. A., and SCHMIDT, J. W.
1963. Nebr. Wheat Newslet. 10: 48.
——— SCHMIDT, J. W., DREIER, A. F., and MATTERN, P. J.
1961a. WARRIOR, A PRODUCTIVE HIGH QUALITY, HARD RED WINTER WHEAT FOR NEBRASKA. Nebr. Agr. Expt. Sta. Statis. Bul. 462, 19 pp.
——— SCHMIDT, J. W., DREIER, A. F., and MATTERN, P. J.
1961b. OMAHA HARD RED WINTER WHEAT. Nebr. Agr. Expt. Sta. Statis. Bul. 463, 23 pp.
LAFEVER, H. M.
1968. REGISTRATION OF LOGAN WHEAT. Crop Sci. 8(4): 512.
LAUDE, H. H., SCHLEHUBER, A. M., PAINTER, R. H., and others.
1952. PONCA WINTER WHEAT. Kans. Agr. Expt. Sta. Bul. 354 and Okla. Agr. Expt. Sta. Bul. B-380, 14 pp.
NOBLE, W. B., CARTWRIGHT, W. B., and SUNESON, C. A.
1940. INHERITANCE OF RESISTANCE TO HESSIAN FLY. Jour. Econ. Ent. 33: 580-581.
——— and SUNESON, C. A.
1943. DIFFERENTIATION OF THE TWO GENETIC FACTORS FOR RESISTANCE TO THE HESSIAN FLY IN DAWSON WHEAT. Jour. Agr. Res. 67: 27-32.
PAINTER, R. H.
1951. INSECT RESISTANCE IN CROP PLANTS. Macmillan Co.
——— JONES, E. T., JOHNSTON, C. O., and PARKER, J. H.
1940. TRANSFERENCE OF HESSIAN FLY RESISTANCE AND OTHER CHARACTERISTICS OF MARQUILLO SPRING WHEAT TO WINTER WHEAT. Kans. Agr. Expt. Sta. Tech. Bul. 49, 55 pp.
PATTERSON, F. L., STIVERS, R. K., LEUTKEMEIER, O. W., and others.
1964. SMALL GRAIN VARIETIES FOR INDIANA. Purdue Univ. Agr. Expt. Sta. Res. Bul. 775, 15 pp.
REITZ, L. P., and BRIGGLE, L. W.
1966. DISTRIBUTION OF THE VARIETIES AND CLASSES OF WHEAT IN THE UNITED STATES IN 1964. U.S. Dept. Agr. Statis. Bul. 369, 68 pp.
——— and LAUDE, H. H.
1943. COMANCHE AND PAWNEE: NEW VARIETIES OF HARD RED WINTER WHEAT FOR KANSAS. Kans. Agr. Expt. Sta. Bul. 319, 16 pp.

ROBERTS, J. P., SLINGERLAND, M. W., and STONE, J. L.
1901. THE HESSIAN FLY: ITS RAVAGES IN NEW YORK IN 1901. N.Y. (Cornell) Agr. Expt. Sta. Bul. 194, 239-260.

SCHAFER, J. F., CALDWELL, R. M., PATTERSON, F. L., and others.
1968. ARTHUR SOFT RED WINTER WHEAT, A BREAKTHROUGH TO A NEW YIELD LEVEL. Purdue Univ. Agr. Expt. Sta. Prog. Rpt. 335, 4 pp.

SHANDS, R. G., and CARTWRIGHT, W. B.
1953. A FIFTH GENE CONDITIONING HESSIAN FLY RESPONSE IN COMMON WHEAT. Agron. Jour. 45: 302-307.

SUNESON, C. A., and NOBLE, W. B.
1950. FURTHER DIFFERENTIATION OF GENETIC FACTORS IN WHEAT FOR RESISTANCE TO THE HESSIAN FLY. U.S. Dept. Agr. Tech. Bul. 1004, 8 pp.

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
BELTSVILLE, MARYLAND 20705